Settlement Due to Tunnel Construction

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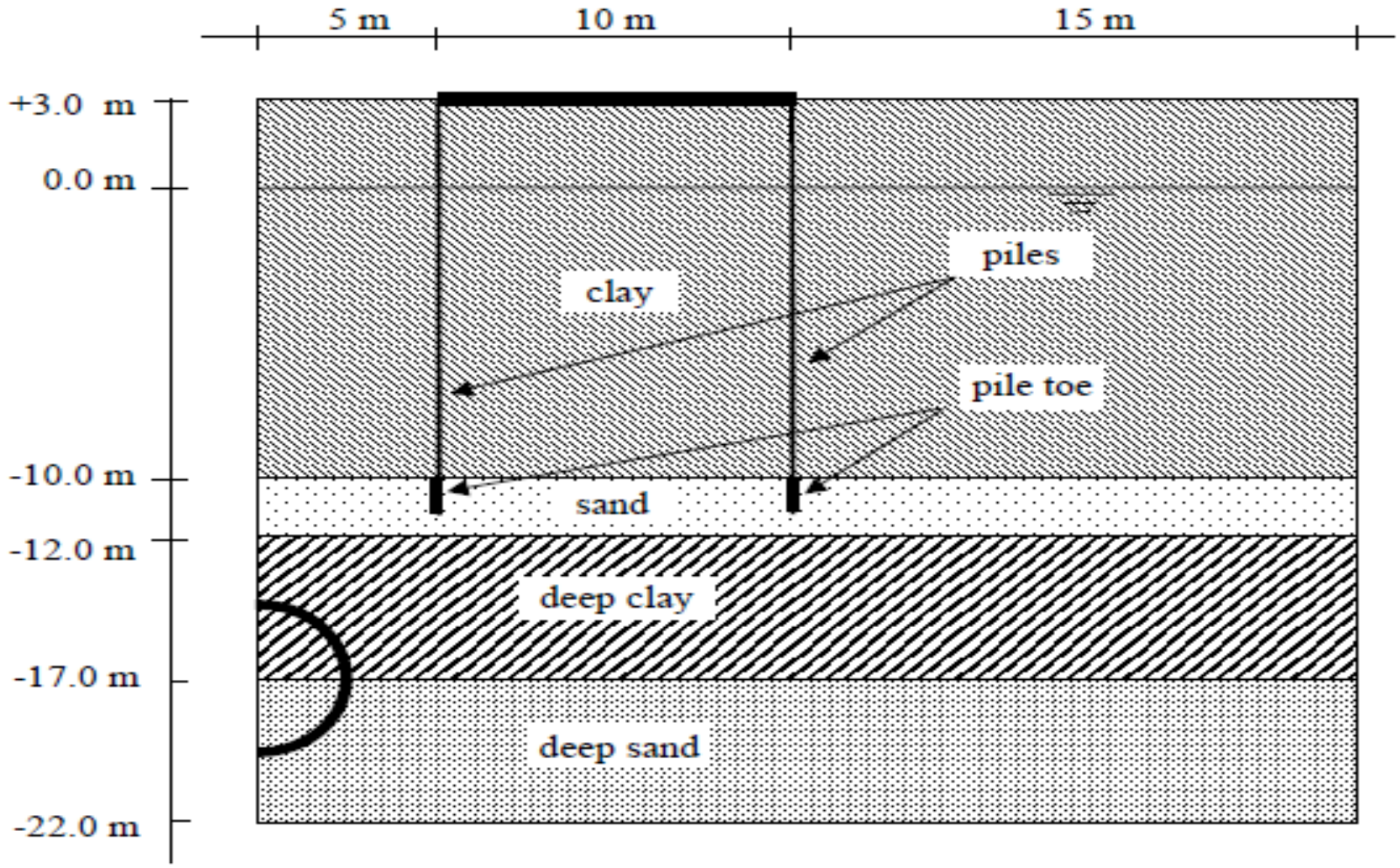
INTRODUCTION

PLAXIS has special facilities for the generation of circular and non-circular tunnels and the simulation of a tunnel construction process. In this chapter the construction of a shield tunnel in medium soft soil and the influence on a pile foundation is considered. A shield tunnel is constructed by excavating soil at the front of a tunnel boring machine (TBM) and installing a tunnel lining behind it. In this procedure the soil is generally over-excavated, which means that the cross sectional area occupied by the final tunnel lining is always less than the excavated soil area. Although measures are taken to fill up this gap, one cannot avoid stress re-distributions and deformations in the soil as a result of the tunnel construction process. To avoid damage to existing buildings or foundations on the soil above, it is necessary to predict these effects and to take proper measures. Such an analysis can be performed by means of the finite element method. This lesson shows an example of such an analysis.

Example


5 m
10 m
15 m
+3.0 m
0.0 m
-10.0 m
-12.0 m
-17.0 m
-22.0 m
clay
piles
pile toe
sand
deep clay
deep sand

Statement of Problem

Tunnel Diameter = 5m

Phreatic surface = 3m below ground surface

The tunnel considered in this lesson has a diameter of 5.0 m and is located at an average depth of 20 m. The soil profile indicates four distinct layers: The upper 13 m consists of soft clay type soil with stiffness that increases approximately linearly with depth. Under the clay layer there is a 2.0 m thick fine sand layer. This layer is used as a foundation layer for old wooden piles on which traditional brickwork houses were built. The pile foundation of such a building is modelled next to the tunnel. Displacements of these piles may cause damage to the building, which is highly undesirable. Below the sand layer there is a 5.0 m thick deep loamy clay layer.

This is one of the layers in which the tunnel is constructed. The other part of the tunnel is constructed in the deep sand layer, which consists of dense sand and some gravel. This layer is very stiff. As a result only 5.0 m of this layer is included in the finite element model; the deeper part is considered to be fully rigid and modelled by appropriate boundary conditions. The pore pressure distribution is hydrostatic. The phreatic level is located 3 m below the ground surface (at a level of $y = 0$ m). Since the situation is more or less symmetric, only one half (the right half) is taken into account in the plane strain model. From the centre of the tunnel the model extends for 30 m in horizontal direction. The 15-node element is adopted for this example.

MATERIAL PROPERTIES OF SOIL LAYERS IN TUNNEL

Parameter	Name	Clay	Sand	Dp. Clay	Dp.sand	Unit
Material model	*Model*	MC	MC	MC	MC	-
Material beh.	*Type*	Drained	Drained	Drained	Drained	-
Soil unit weight above phreatic level	γ_{unsat}	15	16.5	16	17	kN/m^3
Soil unit weight below phreatic level	γ_{sat}	18	20	18.5	21	kN/m^3
H. permeability	k_x	$1 \cdot 10^{-4}$	1.0	$1 \cdot 10^{-2}$	0.5	m/day
V. permeability	k_y	$1 \cdot 10^{-4}$	1.0	$1 \cdot 10^{-2}$	0.5	m/day
Young's modulus	E_{ref}	3400	80000	10000	120000	kN/m^2
Increase E	E_{incr}	400	-	-	-	kN/m^3
Reference level	y_{ref}	0.0	-	-	-	m
Poisson's ratio	ν	0.33	0.3	0.33	0.3	-
Cohesion	c_{ref}	5.5	1.0	4.0	1.0	kN/m^2
Friction angle	φ	24	31	25	33	°
Dilatancy angle	ψ	0.0	1.0	0.0	3.0	°
Interface strength	R_{inter}	rigid	rigid	0.7	0.7	-

MATERIAL PROPERTIES OF PLATE

Parameter	Name	Lining	Pile toe	Building	Unit
Type of behaviour	*Type*	Elastic	Elastic	Elastic	
Normal stiffness	*EA*	$1.4 \cdot 10^{7}$	$2 \cdot 10^{6}$	$1 \cdot 10^{10}$	kN/m
Flexural rigidity	*EI*	$1.43 \cdot 10^{5}$	$8 \cdot 10^{3}$	$1 \cdot 10^{10}$	kNm^2/m
Equivalent thickness	*d*	0.35	0.219	3.464	m
Weight	*w*	8.4	2.0	25	kN/m/m
Poisson's ratio	*v*	0.15	0.2	0.0	-

Parameter	Name	Pile	Unit
Material type	*Type*	Elastic	
Normal stiffness	*EA*	$2 \cdot 10^6$	kN
Spacing between anchors	$L_{spacing}$	1	m

CALCULATION PHASES

- 3 calculation phases will be defined
- PHASE-01
- Select plastic analysis, staged construction and click define and activate the building, anchors and toe plates.
- PHASE =02
- Plastic calculations, reset displacement to zero, staged construction and define and then activate the tunnel linning.

Click the 'switch' to proceed to the water pressures mode. Click the *Selection* button and select both soil clusters inside the tunnel simultaneously (using the <Shift> key). Double-click one of the clusters while holding the <Shift> key. This will show the *Cluster pore pressure distribution* window. In this window select *Cluster dry* and click *OK* to return to the water pressure mode.

Click the *Generate water pressures* button to generate the water pressures. In the resulting plot it can be seen that there are indeed no water pressures inside the tunnel. Click the *Update* button to return to the water pressures mode.

- Phase-03
- There will be some contraction due to dewatering and tunnel lining construction.so apply 2% contraction.